THE INDONESIAN JOURNAL OF BUSINESS ADMINISTRATION
Vol. 2, No. 7, 2013:864-875

PROPOSED PRODUCT DESIGN OF SOLAR STREET LIGHTING SYSTEM USING QUALITY FUNCTION DEPLOYMENT (QFD) METHOD IN PT SOLARE BANDUNG

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Abstract— *The emergence of competition in business is inevitable. With competition, every company faced with both opportunities and threats coming from outside or from within the country. Companies should seek to minimize their weaknesses and maximize strengths. Thus the company is required to select and define strategies that can be used to deal within the competition. PT SOLARE was established in 2004, as a manufacturer of solar home lighting system and at 2007 manufacture a street lighting system. PT SOLARE has never achieved sales target of street lighting system that defined by the management. That was an impact of the intense competition in the industry. It also because PT SOLARE was unable to achieved customer needs and wants from the street lighting system. Root cause need to be determined to know why PT SOLARE unable to achieve the sales target. Business situation analysis and Customer needs and wants analysis need to be conducted. Business situation analyses were conducted by analyze Porter's Six Forces and Ansoff Matrix. Customer needs and wants analysis was conducted by Quality Function Deployment (QFD) method. Based on above analyses, the root causes are PT SOLARE were unable to fulfill the customer need for a product that able to operate in wide battery fluctuation, the selection height of the product according to the provision, and a low temperature LED lamp. Objective of this research is to give a recommendation proposed design of street lighting system for PT SOLARE, suggestion for adding more production lines, some suggestion price from target profit pricing method for the minimal product sales per month for PT SOLARE to get the break-even-point (BEP) and an implementation plan to manufacture the product. These recommendations are expected to help PT SOLARE to achieve the target sales.*

Keywords: Quality Function Deployment (QFD), Solar Street Lighting System, New Product Development.

1. Introduction

Electrification in Indonesia is probably still about 60-70% only. Eastern Indonesia and even below 45%, so there will be a good business if there is a way to make an independent home lightning system and street lighting system.

A. Company Profile

PT. Solare is a manufacturing company which producing a series of solar-powered lighting system which operate since 2004. While the location of the office as well as factory PT. Solare in the area due to Setrasari Mall near the Pasteur toll gate to facilitate the transportation side.

B. Vision and Mision

PT SOLARE vision are being a company which is able to utilize the latest technology for a benefit of large society. And the mission is to make a good quality solar lighting system that can be used by people who live in remote or isolated areas.

C. Organizational Structure

At the Figure 1 below, it show the organizational structur from Makassar Resto which is a simple structure which consist of 6 positions that are director, secretary, production manager, warehouse manager and staff.

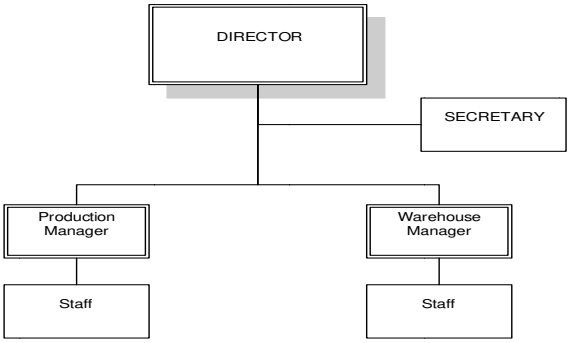

Figure 1. Organization Chart

D. Business Issue

PT SOLARE now faced with obstacle which affected to the company's performance it was caused by emergence of many new competitors in this industry. Every player in this industry competes in providing product quality and customer service. Table 1 shows the sales report from PT SOLARE from 2004 to 2011.

Table 1. PT SOLARE Sales Report 2004-2011

	2004		2005		2006		2007		2008		2009		2010		2011	
	PLTS	PJU	PLTS	PJU	PLTS	PJU	PLTS	PJU	PLTS	PJU	PLTS	PJU	PLTS	PJU	PLTS	PJU
Jan	10	0	75	0	175	0	91	0	6	0	2	0	0	0	0	53
Feb	25	0	120	0	435	20	1	0	35	10	0	19	205	6	107	26
Mar	37	0	150	0	276	0	4	2	401	0	5	8	1	2	5	32
Apr	129	0	135	0	129	35	6	12	4	100	5	0	3	45	0	14
May	337	0	427	3	305	5	1	10	9	0	15	12	0	9	0	9
Jun	146	0	175	0	127	0	13	17	37	5	482	101	0	51	0	16
Jul	70	0	325	0	195	0	32	7	150	10	354	7	2	59	2	11
Aug	65	0	275	5	115	40	29	2	233	0	3	47	0	14	0	14
Sep	184	0	425	0	107	4	495	11	21	53	0	18	0	0	0	23
Okt	12	0	152	0	95	1	18	2	102	2	5	17	0	35	0	32
Nov	50	0	107	10	87	0	604	133	14	2	341	0	1	42	1	45
Des	0	0	85	0	83	9	852	0	2	0	5	1	34	15	34	15
	1065	0	2451	18	2129	114	2146	196	1014	182	1217	230	246	278	149	290

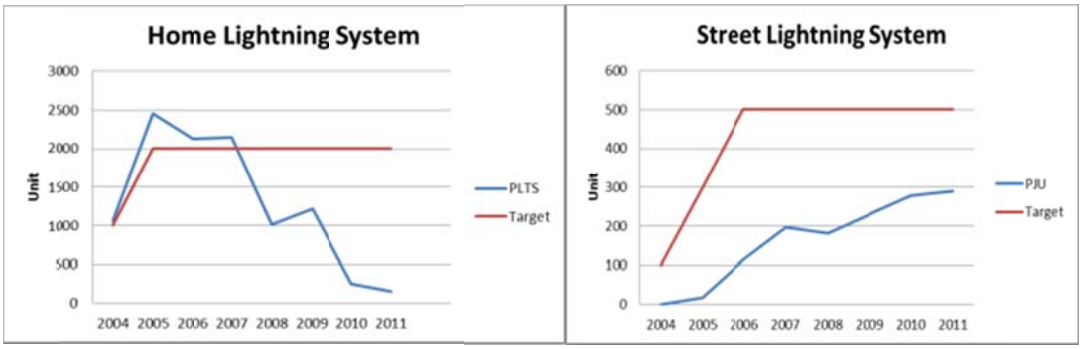

Figure 2 .Home and Street Lightning System Sales Chart

Figure 2 shows the comparion between the desired target sales with the actual sales. Due to the number of companies that sell general lighting highways in and outside the country, PT SOLARE wanted the products to be competitive in the market Quality improvement aimed at the consumer desires will encourage companies to find the best solution so that their products acceptable to consumers. Therefore, the quality control activities are not sufficient merely sorting and inspection activities only. However, based on the criteria that customers want, the company got the idea of product development.

2. Business Issue Exploration

A. Conceptual Framework

Business issue faced by PT. SOLARE is the increasing competition in the street lighting industry. So companies need to be more understand and more sensitive to the information about the needs and desires of consumers to buy its products. It would require a conceptual framework to look at the related factors that could be the root of the problem. Conceptual framework also used as a guide to develop any strategy that can overcome the business issue faced by PT. Solare. A structured conceptual framework is developed by referring to literature study, field observation, and experience. Figure 3 illustrated the Conceptual Framework which is a combination of several theories.

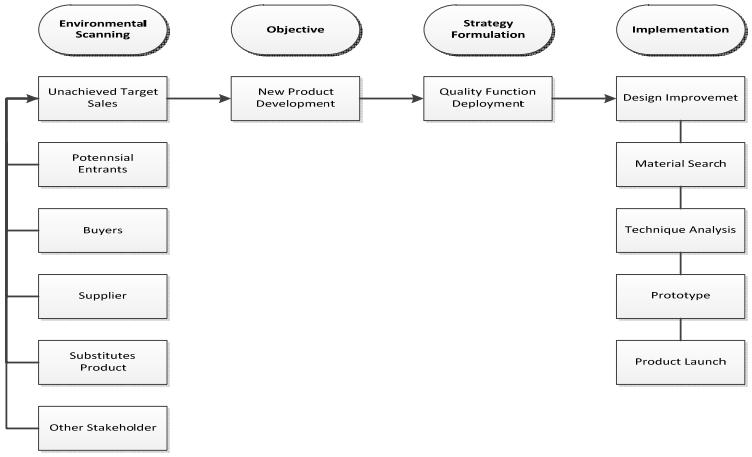

Figure 3. Conceptual Framework

B. Method of Data Collection and Analysis

1. Porter's Six Force Analysis

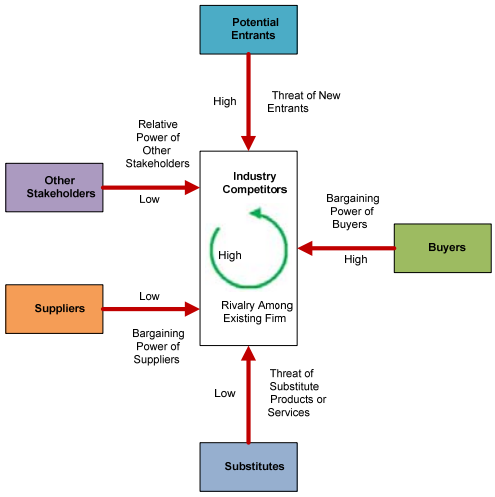

Figure 4 .Porter's Six Force

According to figure 4 above, company must assess the importance to its success of each of six forces:

a. Threat of New Entrants

Threat of potential new entrants in solar powered lighting industry is high because the entry barrier itself is low.

- **Product differentiation**: PT Solare produces solar powered lighting with direct current and using LED light. This decision was taken to reduce components that can affect the life time of

the overall product. The result is consumer cannot change the LED lamp freely, and the end price is more expensive than the other type of product

- **Switching cost:** Switching costs are high for customer if the price are the same. Discount are needed to maintain customer loyalty to avoid the cost of switching by customers. PT SOLARE price are the lowest among the competitor, so the switching cost are low.
- **Government Policy:** Growing concern to reduce dependency on fossil fuel has makes the government trying to boost investment in renewable energy. Actually threat of new entrants in this business sector is relatively high because there's always a new competitor to compete in the street lightning product.

b. Rivalry among Existing Firms

In general, companies in an industry is inter related, therefore competitive movement taken by a company affects and will be responded by its competitors on a competitive basis. In general, intensity of rivalry in this business was high

c. Threat of Substitute Products or Services

A substitute product or service is a product or service that appears to be different but can satisfy the same need as another product or service. Street lights by PT. Solare are using solar panel for the source of energy. Even though there was some method such as geothermal power, wind power, bioenergy and other source energy, solar panel still considered as the best method for lightning energy cost

d. Bargaining Power of Buyers

The bargaining power of buyers in Street lights system are high. Customers have power to control the price, bargain for higher quality, and makes players in this business to keep compete in fulfilling customer demands. Generally, customer wants to have best service at lowest price. The main buyer for solar cell street lights system is the government, The government segment has strong bargaining power since:

1. For them alternative supplier is plentiful.
2. Changing supplier is easy for them and cost very little, because there's a lot of potential supplier to choose from.

e. Bargaining Power of Suppliers

Street lightning business is a business sector that reliant to supplier to provide component to the company to make the street lightning system to its customer. PT Solare have partnership with several companies to run its business, such as LED factory in china, solar cell factory, forwarder company, etc. But the bargaining power of supplier in this industry is low. The suppliers for PT. Solare are very easy to replace because of the large number of supplier available.

f. Relative Power of Other Stakeholders

The media has a potential impact because publication can help the positive image that can elevate the positioning of the brand that the company had in the mind of their customers. While regulation from the government supports the company who sells an alternative energy product.The relative power of other stakeholders are considered low because didn't affect much to the business industry

2. Ansoff Matrix

Ansoff's matrix (Drummond.G.et.al.2001:161) suggests four alternative marketing strategies which hinge on whether products are new or existing. They also focus on whether a market is new or existing.

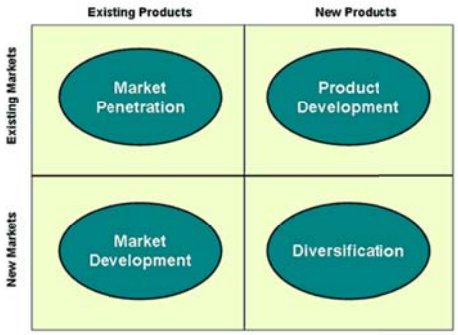

Figure .5 Ansoff matrix

According to figure above, to win the competition in an existing market by new product, the best way is to be a pioneer by developing a new product. Quality Function Deployment (QFD) is one method to develop a new product (Cohen, 1995:11)

3. Quality Function Deployment

Figure 6. Garvin 8 Dimension of Quality

David Garvin (2003:219) has identified eight different quality dimensions. Which are :

Here is an explanation of the relationship dimensions with attributes:

1) Durability

Durability is a useful life of a product or service, so all components are made with durable considerations. Such as:

- LED-lamp are capable of operating on quite wide battery voltage fluctuations
- LED component temperatures remains low
- Non-rusting component.

2) Performance

Aspects of performance to be a major consideration in the design of street lightning products such as :

- most efficient LED seen from the ratio between the electrical power used in watts for lighting levels required
- The distribution of light is quite wide

3) Feature

Featured usually are additional amenities or attributes of a product, in the street lighting product, the addition lies on accessories which support main function.

4) Conformance

Conformance to the solar panel street lighting matches the specifications of standards have been established, such as meeting ISO and qualified consumer desires

5) Reliability

Reliability aspects to be considered in the design of products as follows:

- Selection of components that have such long service
- All the material have a high safety factor.

6) Serviceability

Serviceability is the capacity, speed and ease of repair. In Solar panel Street lightning, the ability and ease of repair is to provide warranty

7) Aesthetics

Dimension of aesthetics are related to how the appearance or taste of a product. In this PJU products found in the design of all components

8) Perceived Quality

- Material of main poles, lamp poles and head lamp gives the impression of more luxurious.
- Discount for customers

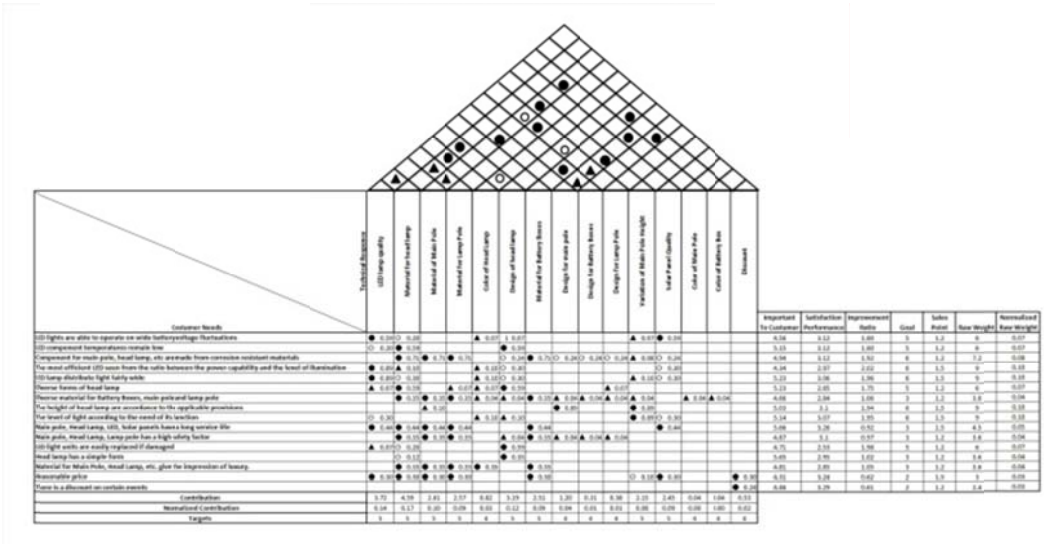

Figure 7. House Of Quality

Based on figure 7 above, these following are the top five priorities of the customer needs:

1. LED Lamp distribute light fairly wide
   LED Lamp distribute fairly wide light that has a value of 0.098 Normalized raw weight ranks first in priority order. In this case the customers think that the wide light distribution are important. There are some parts that affect the wide distribution of the light generated from the LED lamps, such as LED lighting quality and design head lamp. For wide angle coverage, the design of LED Bulb can be positioned with different angle, so any angle of illumination or wide coverage can be achieved by the design of LED Bulb.
2. The height of head lamp are accordance to applicable provisions
   The height of head lamp are accordance to applicable provisions has a raw weight normalized value of 0.098 and ranked second in priority order. The height of head lamp is an important factor for consumers in choosing a product, in this case is the product of solar street lighting. That's because the requirements of the minimum height for street lights and what kind of traffic that runs underneath. The height of head lamp can be influenced by the material of a main pole. The material will determine which are the main pole are strong enough to withstand the lamp pole, solar panel and head lamp that attached to it at a certain height.
3. The level of light according to the need of its function
   The level of light according to the needs of its function is the third in order of priority with the raw weight normalized value of 0.098. The intensity of light is an important component

of public street lighting products. Quality of LED Lamp is the most important thing from the level of light.

4. Component for main pole, head lamp are made for corrosion resistant materials
   In the fourth order in priority with value of raw normalized weight of 0.079 are Component for main pole, head lamp are made for corrosion resistant materials. Corrosion resistant materials became into one of customer consideration for the street lighting products. So the material with steel structural components made with galvanized coating that keep it from rusting and extend the life chances components
5. LED lights are able to operate on wide battery voltage fluctuation
   LED lights are able to operate on wide battery voltage fluctuation is the fifth order of priority with the raw weight normalized value of 0,066. Customer feels that the LED lights are capable of operating on a large enough battery fluctuations are important in public street lighting products. LED lamp quality and a heat sink that can operate as a heat sink for led lamp are essential to keep the lights can still operate well in a large battery voltage fluctuation.

And these are top 5 of priority technical response based on figure 7 House of Quality:

1. Material for head lamp
   'Material for head lamp' is in the first list of priority, because it has a normalized contribution value of 0.17. Material for head lamp is very important in street lighting products because it has a considerable influence on customer needs. To meet customer satisfaction is by choosing a new material, therefore giving the company a target value with scale 5, the new material of head lamp are expected to meet the needs and desires of consumers.

2. LED lamp quality
   LED lamp quality are in the second list of priority, because it has a normalized contribution value of 0,14. By choosing a good quality of led lamp, it will affect the customer needs criteria because the better the quality of led lamp, the better the led lamp to operate in good condition.
3. Design of head lamp
   To attribute design of head lamp has a normalized value of contribution by 0.12. Placed in the third position in the order of priority of technical characteristics. The design if head lamp may affect the ability of the LED lights because it can be a heat sink to keep the temperature of the LED lights remain low. Design of head lamp can also affect the spread of the light by giving a certain angle on the holder lamp.
4. Material for main pole
   Material for main pole is in the fourth order of priority because it has the characteristics of normalized contribution value of 0.10. The good main pole are not easy to rust and withstand strong with heavy load that attached to it.
5. Material for lamp pole
   For the fifth priority contained technical characteristics of material for lamp pole with the normalized contribution value of 0.09. Good material for a lamp pole is fairly lightweight material but is resistant to rust but strong enough to bear the weight of head lamp.

C. Root Cause Analysis

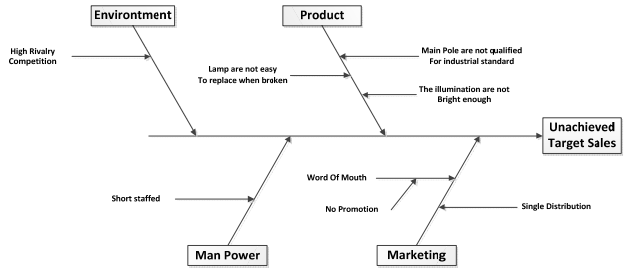

Figure 8. Fishbone Diagram

Based on the fishbone diagram above, can be seen that the factors which cause an unachieved target sales of a street lighting system are the environment, head lamp, main pole and LED Lamp. Which can be described as follows:

- Environment
  The intensity of rivalry in this business was high. And also the Increases of new competitors that make the customer have a different choice when they want to buy a street lighting system.
- Man Power
  PT SOLARE staffs are just 7-10 people. PT SOLARE cannot add more staff because of the number of orders were few and limited production floor.
- Marketing
  For marketing the product, PT SOLARE appoint CV. Citra Surya Utama (CSU) to be a single distribution so PT SOLARE can focus on production. Other marketing methods are word-of-mouth marketing from the customer. Less marketing method makes the target sales are not achieved.
- Product
  - LED Lamp

  Customer wants a LED lamp to be able to operate in wide battery fluctuation and current street lighting system from PT. Solare are not operating well in the wide battery fluctuation. That's makes a customer prefer a product from another competitor
  - Main Pole

  Main pole height have an industrial standard of height which are:

  a) For Highway street lighting with a height of 13 meters lights
  b) For street lighting which is not a highway with a height of 9 meters lights
  c) For street lighting in urban areas with a height of 7 meters lights
  d) For lighting on rural roads with a height of 5 meters lights

  current PT Solare main pole are only in 5 and 7 meters height. So PT Solare cannot provide the system for highway and street lightning that not for highway criteria.
  - Head Lamp

  Based on importance to customer needs, customer wants to have a street lighting system that have a low temperature LED component, long service life in LED lamp and simple form of head lamp design that can be replaced easily when the lamp are broken. New head lamp design can fulfill the customer needs by a new head lamp design that can provide those application that customer wants like a head lamp that serve as a heat sink to the LED lamp so the lamp will always in low temperature state.

3. Business Solution

From the result of table matrix and technical planning matrix these are some conclusion in what customer wants and needs from a street lighting products:

1. Based on customer needs, in first order of priority are "LED Lamp distribute light fairly wide" and characteristics techniques of those attributes are :

- LED lamp quality
  Good quality of LED lamp distribute a wider light
- Material for head lamp
  Material for head lamp can help LED Lamp to operate in low temperature to maintain the light distribution.
- Variation of main pole height
  Pole height can affect the distribution of light.

2. Second priority based on customer needs is "The height of head lamp are accordance to the applicable provision". and characteristics techniques of those attributes are :
   - Material of main pole
     Material of main pole are supposed to be strong enough if the pole are 5-13 meter height.
   - Variation of main pole height
     Street lighting system have 4 provision of height, those provision are 5 meter for rural area, 7 meter for real estate, 9 meter for non-highway road and 13 meter for highway road
3. 'The level of light according to the needs of its function' is the third priority based on customer needs. and characteristics techniques of those attributes are:
   - LED lamp quality
     The intensity of light for street lighting is 10-20 lux. A good quality of LED Lamp can produce a constant intensity of light on those light intensity.
   - Variation of main pole height
     The height of main pole should not affect the level of light intensity.
4. The forth priority based on customer needs are 'Material for main pole, Head lamp, are made from corrotion resistant materials'. And characteristics techniques of those attributes are:
   - Material for head lamp
   - Material for main pole
5. LED light are able to operate on wide battery voltage fluctuation is the fifth priority based on customer needs. And characteristics techniques of those attributes are
   - LED lamp quality
     A good quality of LED lamp are able to operate in wide battery voltage fluctuation.
   - Material for head lamp
     Material of head lamp should became a heat sink for the LED Lamp to operate in low temperature.
   - Design of head lamp
     Design of head lamp are designed to remove the heat from the material as quick as possible

These are some suggestions from the researcher to the company in the design of street lighting products:

1. LED Lamp
   According to international standards, the intensity of light for street lighting is 10-20 lux (energyefficiencyasia.org, 2007)
   Figure 9 below are some of the types of LED on the market.

Figure 9. Types of LED lamp

Table 2. Lux Meter

LED LAMP	WATT	Height (Meter)												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Type A	0.732	21	6	3	1	-	-	-	-	-	-	-	-	-
Type B	1.452	42	12	6	3	2	1	-	-	-	-	-	-	-
Type C	2.184	66	18	9	6	5	4	3	2	-	-	-	-	-
Type D	2.868	89	25	12	7	6	5	4	3	-	-	-	-	-
Type E	4.332	133	36	17	10	7	6	5	4	-	-	-	-	-
Type F	12.24	-	85	38	22	15	11	8	-	-	-	-	-	-
Type G	15.648	350	106	50	30	21	16	12	10	8	7	6	5	4
Type H	22.956	480	147	68	41	30	22	16	14	10	9	7	6	5
Type I	30.144	684	182	87	53	37	28	21	18	13	12	10	8	7
Type J	40.296	850	238	114	69	47	35	27	22	18	15	13	11	9
Type K	50.52	1250	343	167	97	66	49	37	30	24	21	17	14	12
Type L	58.08	1201	399	199	117	80	59	45	36	29	24	20	17	14

Based on table 2 above, this are the selected type of LED lamp for each of Street lighting system:

- For Highway street lighting with a height of 13 meters lights, the researcher recommends using LED lights type K or type L to get a light intensity of 12-14 lux.
- For street lighting which is not a highway with a height of 9 meters lights, the researcher recommends using LED lights type H, type I or type J to get a light intensity of 10, 13 or 18 lux.
- For street lighting in urban areas with a height of 7 meters lights, the researcher recommends using LED lights type G or type H to get a light intensity of 12 or 16 lux.
- For lighting on rural roads with a height of 5 meters lights, the researcher recommends using LED lights type F to get a light intensity of 15 lux.

2. Main Pole
   Main pole that customers want is a main pole which is rust-resistant, sturdy and able to withstand the load attached to the main pole. Consumers also wants main pole height are in accordance with the high standard of public street lighting products, namely 5, 7, 9 and 13 meters. The material that a researcher proposed to PT Solare is a component of the structure which made from steel with a galvanized coating that keep it from rusting and extend the life chances of these components.
3. Head Lamp
   Out of five key criteria that consumers want, four of them were associated with head lamp. The ideal head lamp is a head lamp that can be a heat sink for the LED lights so LED lights can function optimally, can provide the perfect angle for the LED lamp holder so that the light can spread wider and made from corrosion-resistant material.

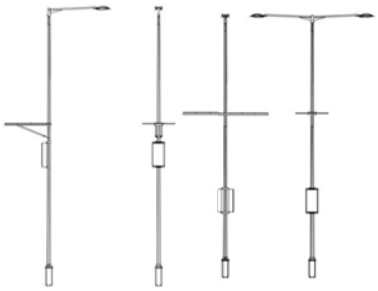

Figure 10. Street Lightning Concept

Figure 10 are the final concept for the new street lighting system for PT SOLARE with the criteria :

a. Main Pole height according to the provision of the height according to the traffic that runs underneath it which is 5, 7, 9 and 13 meters.
b. Main pole, head lamp, battery boxes, lamp pole are made from galvanized steel that have an anti-corrosion resistant material.
c. Head lamp also functionate as a heat sink for LED lamp.

d. LED lamp light intensity are bright enough according to the provision and distribute light fairly wide.

Target profit pricing are a pricing method by identifying the price at which a product will be competitive in the marketplace, defining the desired profit to be made on the product. Table below are a several target pricing for PT SOLARE to determine the product sales of the product.

Table 3. Target Profit Pricing

Fixed Cost	Variable Cost	Target Profit	Margin	Selling Price	BEP
42,833,333	41,000,000	5%	2,141,667	43,141,667	39.14
		10%	4,283,333	45,283,333	19.09
		15%	6,425,000	47,425,000	12.72
		20%	8,566,667	49,566,667	9.54
		25%	10,708,333	51,708,333	7.63
		30%	12,850,000	53,850,000	6.36
		35%	14,991,667	55,991,667	5.45
		40%	17,133,333	58,133,333	4.77
		45%	19,275,000	60,275,000	4.24

Based on table 3, PT SOLARE can determine the price based on the target profit that PT SOLARE desires. With the target profit of 5%, the Break Even Point (BEP) are selling 39,14 or 40 product per month. If the target profit are sets for 10%, the BEP are in the 20th product that PT SOLARE sells. Comparison of the proposed price was still cheaper compared to products from other competitors that currently exist which prices range between Rp 45.000.000,- until Rp 60.000.000,-.

4. Conclusion and Implementation Plan

Based on questionnaire data processing and observation on business situation, it can be concluded that PT Solare needs to design new product that fulfill the customer needs if the company wants to meet the target sales and compete against other competitor for the street lightning product. matrix of Quality Function Deployment (QFD) are used to find out information about consumer wants and needs of a product. With QFD method is expected to be with the right tools for the company to produce a street lighting system product which in accordance with the needs and desires of consumers.

There are several suggestion for PT. Solare new product of street lightning system, but only the best solutions with comparison of benefit and cost are selected. The selected solution of every problems are as follows:

1. Main Pole
   Structural components or material of main pole are made of steel with galvanized coating, has four height range from 5, 7, 9 and 13 meters.
2. LED Lamp
   For Highway street lighting with a height of 13 meters lights use LED type K or type L in order to get the illumination level 12-14 lux.For street lighting which is not a highway with a height of 9 meters lights use LED type H, type I or type J in order to get the illumination level 10, 13 or 18 lux.For urban areas street lighting with a height of 7 meters lights use LED type G or type H in order to get the illumination level 12-16 lux.For street lighting in the rural area with a height of 5 meters lights use LED type F in order to get the illumination level 15 lux.
3. Head Lamp
   Head lamp is designed in such a way that it could be a heat sink for the LED lights, the angle of led holder so the spread of the light to the road are more than 60 degrees to either side of the road, and made from stainless steel that keep it from rusting and has a long service life.

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